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Nine Phase Transformer through MLI Base Stand Alone Integrated Wind Energy System

D.Anusha[1], L.V. Suresh Kumar[2]

PG Student [P&ID], Dept. of EEE,GMR Institute of Technology, Rajam, Andhra Pradesh, India[1]

Assistant Professor, Dept. of EEE, GMR Institute of Technology, Rajam, Andhra Pradesh, India[2]

daki.anusha92@gmail.com[1], lvenkatasureshkumar@gmail.com[2]

ABSTRACT: The global electrical energy consumption is rising and there is a sudden increase in the demand of power generation. Large number of renewable energy units is now being integrated to power system for meeting and rising demand of power generation. The present technology used in wind turbines was based on squirrel cage induction generator or permanent magnet synchronous generator straightly connected to the load through standard power electronic converters. In this paper, nine phase winding transformer through multilevel inverter base stand alone integrated wind energy system for reducing harmonics with multi carrier pulse width modulation techniques is proposed. The results establishes the proposed stand alone system performance in both open and closed loop for harmonics, voltage and current responses at linear loads at different wind conditions with energy storage system. And the comparison analysis is presented. The proposed system is developed in MATLAB/SIMULINK.

KEYWORDS: Wind energy system, Multi Winding Transformer, Multi Level Inverter Topologies, Modulation Strategies, Operation of DCMLI

I.INTRODUCTION

In recent years with growing concerns over carbon emission and uncertainties in fossil fuel supplies, there is an increasing interest in clean and renewable electrical energy generation. The technology used in wind turbines was based on squirrel cage induction generators or permanent magnet synchronous generators are directly connected to the system [1]. A wind turbine is a revolving machine that works as kinetic energy capturing from the wind is converted into mechanical energy. This mechanical energy is then converted into electricity by passing through the generators. This will connect to the power system through transformers and converters [2]-[4]. The turbine components are the main objectives for these energy conversions are the rotor and the generator. There exist a huge range of possible wind turbine configurations. Most commonly wind turbines are sorted into the two major categories of “fixed speed turbines” and “variable speed turbines”.

In past years there are using single wind energy system connected to the grid or load but at present proposed technology there are several variable speed wind energy systems are connected to the system to generate high voltage with low amount of cost. Variable speed wind turbine has several advantage compared with fixed speed wind turbine is yielding maximum power output and developing low amount of mechanical stress Here three wind energy conversion systems are connected to the load and this is standalone wind energy system unit and from these three energy units nine phase voltages is generated. This nine phase voltage is converted into three phase voltage with a new developed star/delta nine phase to three phase converted transformer [5]-[6]. The variable voltage and frequency coming from these units to fixed voltage and frequency by using back-back power electronic converters. Here Multi level inverter [7]-[8] is developed in the system with multi carrier pulse width modulation techniques [9] to reduce total harmonic distortion and to control the voltage with energy storage system with variable load [10].

The brief of this paper is as follows. Section II deals with the wind turbine modelling. It is followed by the Multi level inverters and their modulation strategies are discussed in section III-IV. Energy storage system for dc link capacitor and response of the system are shown in section V-VI.

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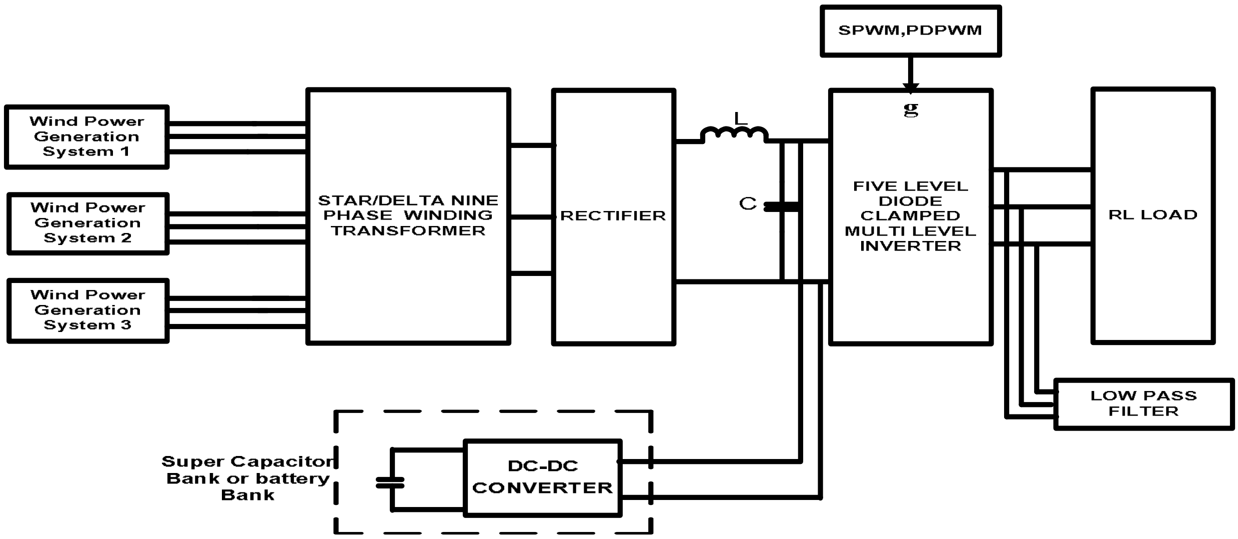
II. PROPOSED SYSTEM

The standalone multi wind energy system presented in this paper with developed multi winding transformers and multi level inverters. The system performance can be observed in two methods, those are:

a) Open Loop System
b) Closed Loop System

a) Open Loop System:



b) Closed Loop System:

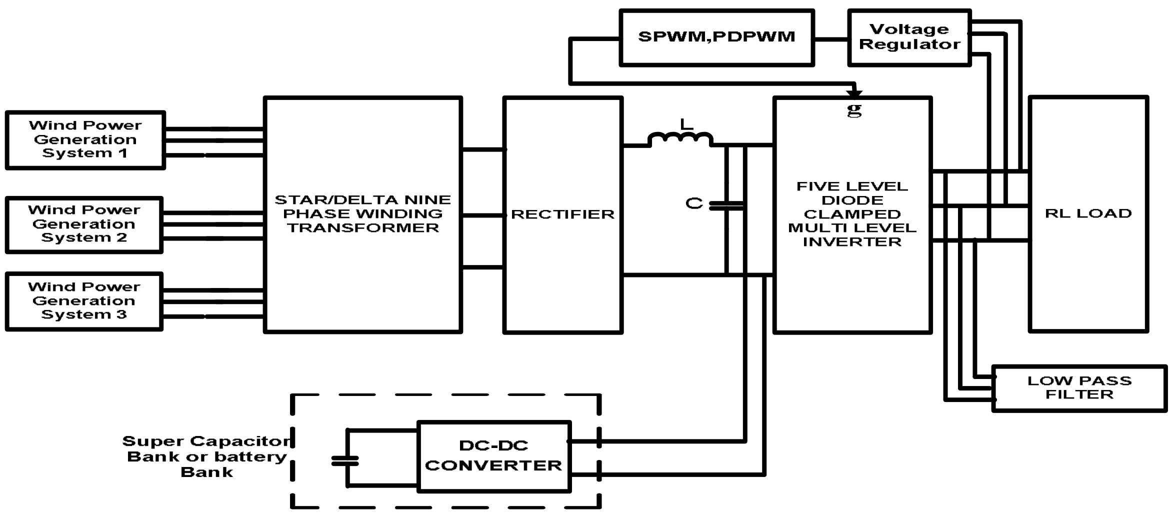


Fig. 1 Power circuit topology of a multi variable speed a) Open Loop b) Closed loop stand-alone wind energy supply system

Fig. 1 & 2 shows the stand alone multiple wind energy systems through nine phase winding transformer with five levels Diode Clamped Multi Level Inverter. In open loop system three wind energy systems are taken as a source and these are connected to the power system that is RL load through nine phase winding transformer and power electronic back to back converters. And all the results are observed with sinusoidal pulse width modulation and Multi Carrier pulse

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generation techniques that is Phase disposition Pulse Width Modulation Technique. Coming to closed loop system for controlling the voltage, the feedback voltage will be taken from load side and this will be summed with generation side voltage and this will be controlled through PI and PID controllers and these will be generated sinusoidal voltage and it can be applied as a modulation index in pulse generation sections for gate signal to inverter.

III. WIND TURBINE MODELING

The wind turbine is most important part in wind energy generation system. In it's the mechanical power is mainly depends on the power coefficient C_p is product of the tip speed ratio λ and the pitch angle of the turbine blade $\theta_{blade.}$ The tip speed is defined ratio of increasing linear speed by the tip of blade and the wind generated speed [1]-[4].
Model of the wind turbine:
The full amount turbine power to be generate from the wind is written as

$$P_{turbine} = 0.5\rho AV^3 C_p(\lambda, \theta_{blade}) \quad (1)$$

Where ρ is the air density (kg/m^3)

A is the swept area (m^2) and $A = \pi r^2$ (m^2)
V is the wind velocity (m/s)
C_p is wind turbine power coefficient
λ is the tip speed ratio
θ is the pitch angle of the blade

There exist a huge range of possible wind turbine configurations. Most commonly wind turbines are sorted into the two major categories of "fixed speed turbines" and "variable speed turbines". The fixed speed wind turbines more frequently used with induction generators and variable speed wind turbines used with double fed induction generators and permanent magnet synchronous generators [4]. These wind turbines captures wind energy from the wind and converts into mechanical energy that is torque and converted into electrical energy by passing through the generator.

IV.NINE PHASE TRANSFORMER

One or more number of winding transformers are used in different applications, but here it is presented in its paper as used to inter connect the different speed wind energy systems to load. Its main advantage is to reduce number of transformers, fitting cost less and less space engaged so more saving for one or more winding transformer consists three three phases star winding at primary side and one three phase delta winding at the secondary side [5]-[6].
Transformer primary side star winding connection connected to three phase generators, it produce three phase voltage at the delta connected secondary side ,this transformer converts one form of voltage to another form of voltage without changing frequency .

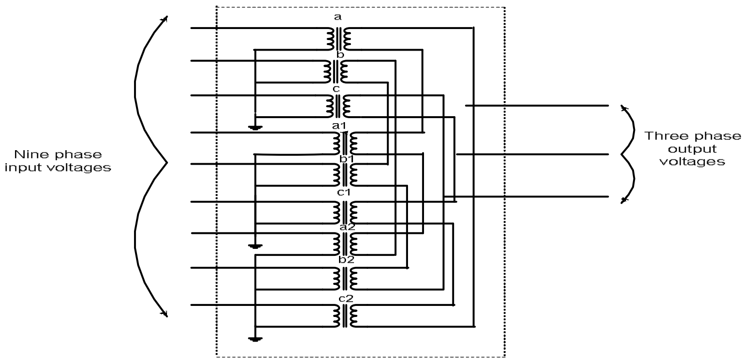

Fig. 2 nine phase to three phase transformer

V. MULTI LEVEL INVERTERS

In back to back power electronic converter connection in the stand alone integrated system there is one rectifier and one inverter is connected in back to back connection mode and which is connected through dc link. These are mainly used to convert variable voltage and frequency coming from the wind generation units in to fixed voltage and frequency. Mainly the inverter operates as it converts ac input voltage to dc output voltage and these normal inverters will produce more harmonics and these harmonics will interrupts the performance of the system so for this multi level inverters will placed due to the advantage of reliable and less harmonic content.

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For getting fewer harmonic distortion the normal inverters was replace with multi level inverters and these are operated with power electronic switches IGBT's or MOSFETS depends on the voltage rating. The multi level inverters can be classified into three main categories [7]. According to improved output response and load requirement the multilevel inverters are used and are mainly classified as (i) Diode clamped multi level inverter (ii) Capacitor clamped or flying capacitor multi level inverter **(**iii) Cascaded multilevel inverter multi level inverter [7]-[8].In this paper five level diode clamped multi level inverter is placed in back to back power electronic converter scheme.

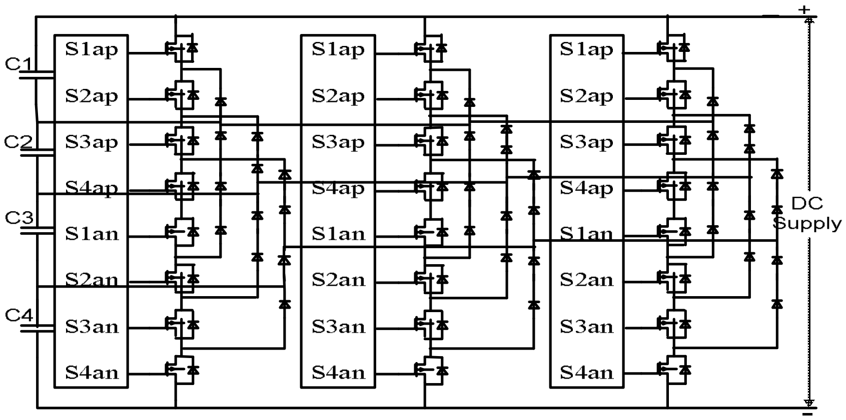


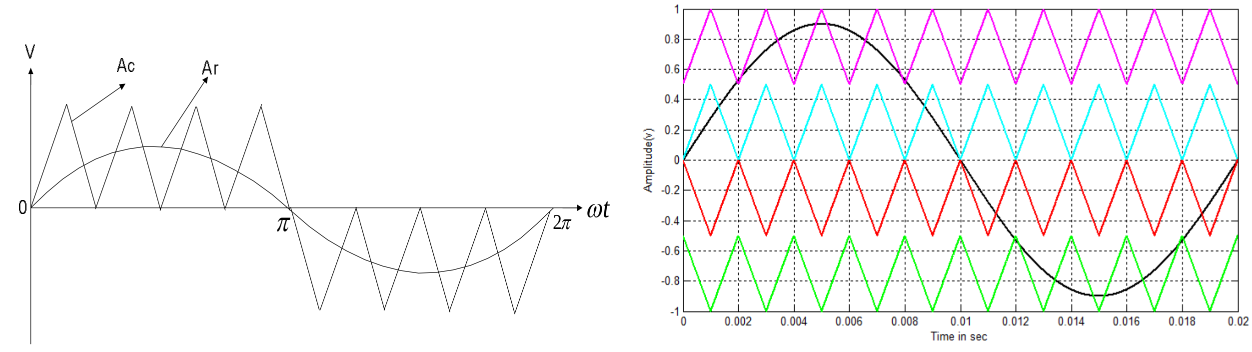
Fig. 3 Schematic for five level diode clamped multi level inverter

This inverter can operates as depending on the switching states of power electronic switches. It consists of (M-1) capacitors placed on the dc bus and produces M levels on the line and phase voltage and number of clamping diodes (M-1) (M-2) and 2(M-1) switching devices that is switches per arm. The four capacitors in the inverter distribute the voltage coming from the input dc into equal sharing so the voltage in each capacitor device is $V_{dc}/4$.

In this inverter each switch is switched on only once per cycle, there are mainly four pairs of switches in addition of both upper and lower arm thus one of the switch pair is switched on then the other pair must be switched off so four switches switched on at the same time and another will be in off position.

VI. MODULATION STRATEGIES

Multi level inverters have more number of switches so it requires more number of gate signals for these switches. Hence multiple pulse generation techniques are used. In this paper mainly using sinusoidal pulse width modulation and phase disposition pulse width modulation for pulse generation and control the multi level inverter and to generate pulses to switches. The multi carrier based pulse width modulation is obtained by comparing the reference sinusoidal signal with triangular carrier signal.



(a) (b)

Fig. 4 Modulation Techniques a) Sinusoidal PWM b) Phase Opposition Disposition PWM

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For M level inverter the M-1 carrier signals are required hence for here ,for five level inverter four carriers are required and these have certain amplitude and frequency and also the sinusoidal reference signal also have the amplitude and frequency. When the reference sinusoidal signal is greater than the carrier triangular wave then the positive pulse is generated and when the reference sinusoidal signal is lesser than carrier wave negative pulse is generated. Below the SPWM and PDPWM presented.

In Phase Opposition Disposition pulse width modulation is one of the most significantly used techniques. In this reference signal is placed at the centre of the carrier signals and all the four carrier signals above zero reference frame are in same phase and below reference frame are as in same phase and phase opposition to the above zero reference frame that is 180^0 and the and reference signal is continuously compared with the carriers [8]-[9].

Compared to sinusoidal pulse width modulation technique the phase Opposition disposition technique will give better system performance and less harmonic distortion.

VII.ENERGY STORAGE SYSTEM

The energy storage system have a super capacitor bank or a battery bank and a two-quadrant dc/dc buck boost converter connected to the dc link .The dc/dc converter contains two insulated-gate bipolar transistor (IGBT) switches S1 and S2.the dc/dc converter can operate in two modes: buck mode and boost mode.

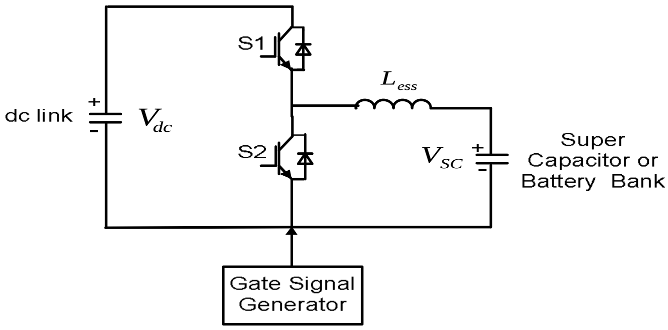

Fig. 5 Schematic of Energy storage system

If S1 is open, the dc/dc converter operates in the boost mode. If S2 is open then operates in buck mode. The control of this energy storage system that is bidirectional buck boost converter which is connected between the dc link and the battery banks to maintain dc link voltage constant without any fluctuations. These fluctuations are arises due to the sudden change of wind speed, when these fluctuations increases then system performance will get harmonics so when the excess voltage comes from the wind generation systems this energy storage system will store this voltage and in this case act as a sink and the voltage in the battery banks increases. Whenever the low amount of voltage coming from the generation systems then this energy system will supplies the voltage to the system from the battery banks hence in this case it will act as a source to the system and the voltage in the battery banks will decreases [10] .

VIII.RESULTS AND DISCUSSION

The below simulated results are performed for nine phase transformer through multi level inverter base stand alone wind energy system with open loop and closed loop system with multi carrier pulse width modulation technique as PODPWM.

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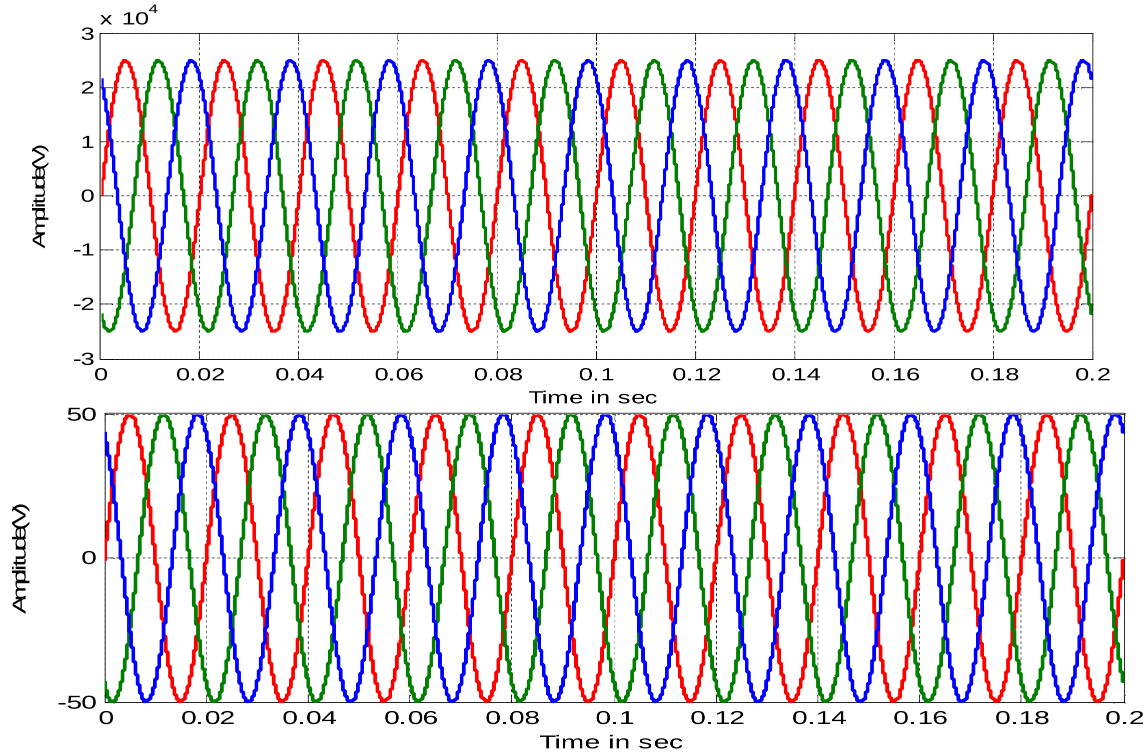

Fig. 6 primary input voltage and currents of the transformer

Fig. 6 explains the primary input voltages which are captured from the different wind generation systems for different wind speeds and the current for the primary side is also presented and the primary side voltage is 25KVolts obtained from three wind energy systems.

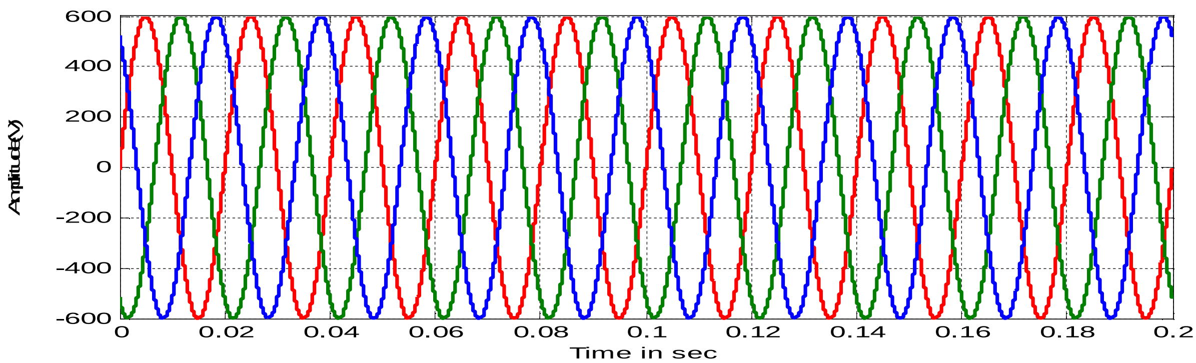

Fig. 7 Secondary output voltages of the transformer

Fig .7 explains the nine phase transformer output voltage that is three phase output voltage obtained from the nine phase voltages from the three wind generation units. It is observed that the secondary side voltage will be obtained as 600Volts from the primary 25KVolts hence this transformer act as a step down transformer.

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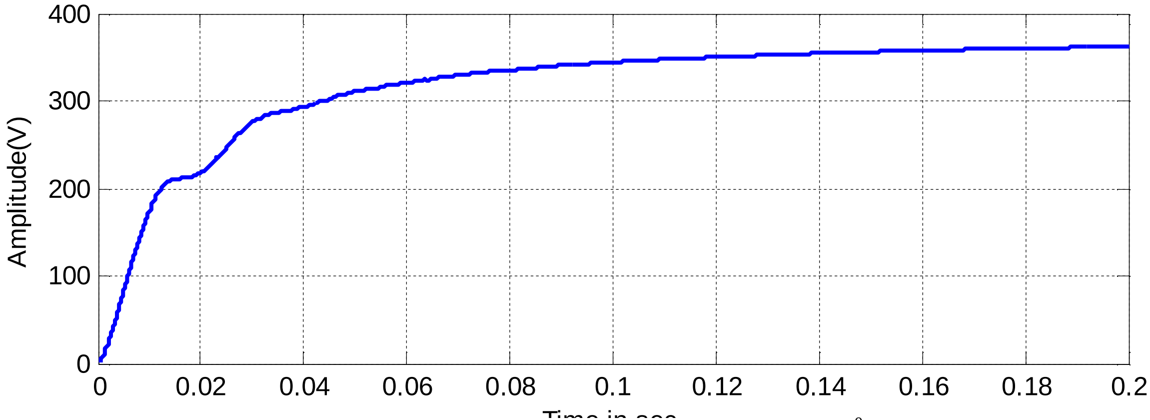
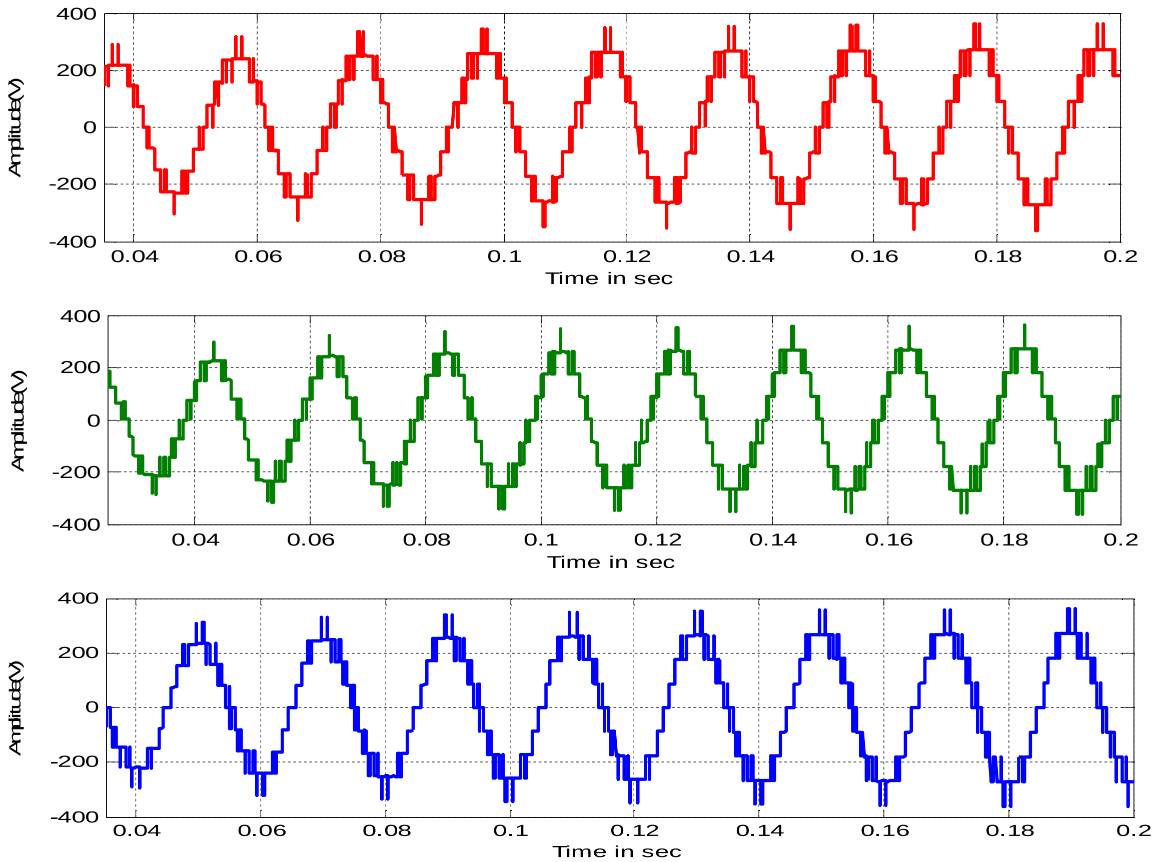


Fig. 8 Output voltage of the rectifier for firing angle 30^0

Fig .8 explains 600V input ac voltage is applied to the rectifier, and the output voltage obtained from the rectifier is 370Volts.This voltage will be applied to the multi level inverter as an input.



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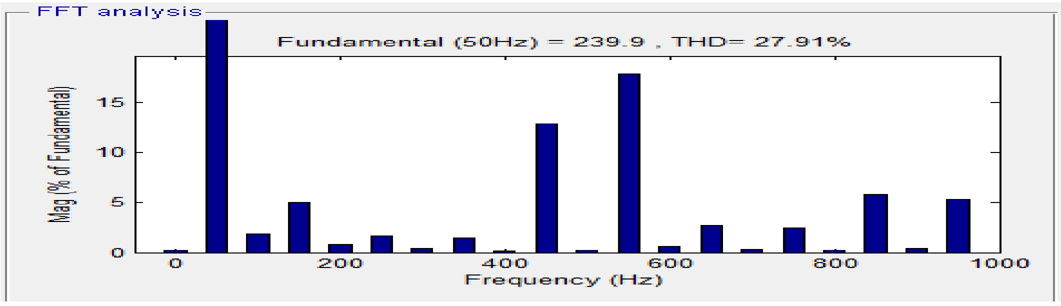

Fig. 9 Three phase five level output voltage of the open loop system and FFT analysis for RL load

Fig. 9 explains the five level output ac voltage of the diode clamped multi level inverter .Hence for input 360V DC the output line voltage of the inverter is 350Volts AC voltage. The harmonic analysis for system performance with this five level inverter is 27.91% with phase Opposition disposition technique (PODPWM).

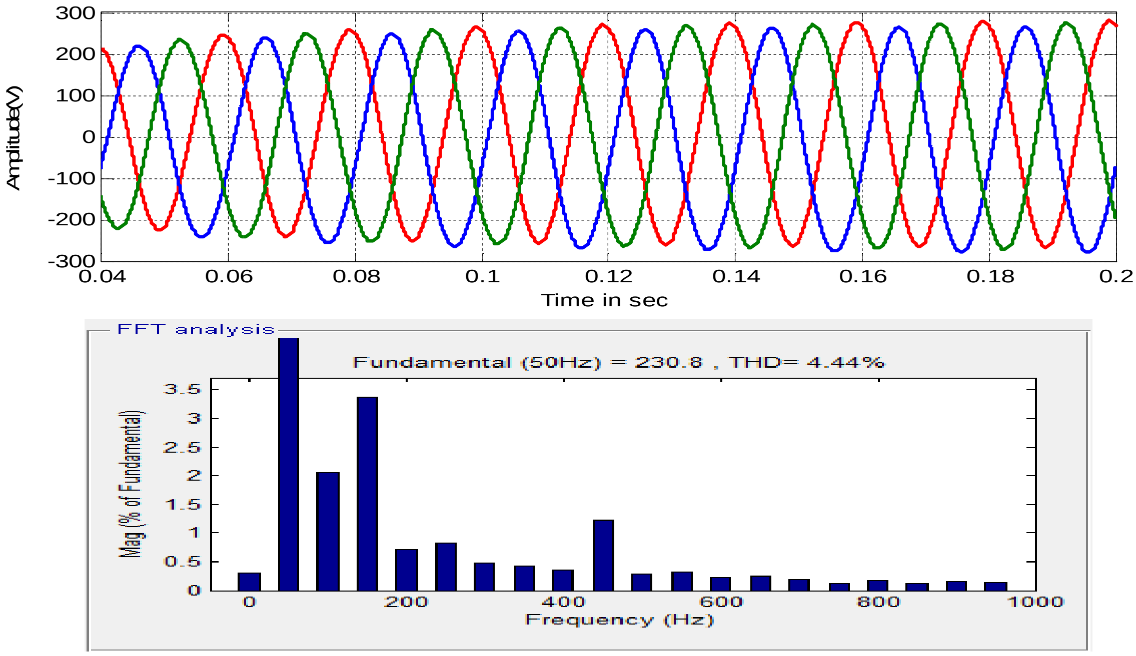

Fig. 10 Three phase five level output voltage and FFT analysis of the open loop system with filter for RL load

Compared to sinusoidal pulse width modulation technique phase disposition technique will improves system performance with fewer harmonic. The RL load applied to this proposed system is R=10Kohms and L=50e-6. And the fig. 10 explains the low pass seconder filter is connected to the system then the effected harmonics will be reduces and the harmonic THD value is decreases up to 4.44% and the above showed results will explains for open loop system.

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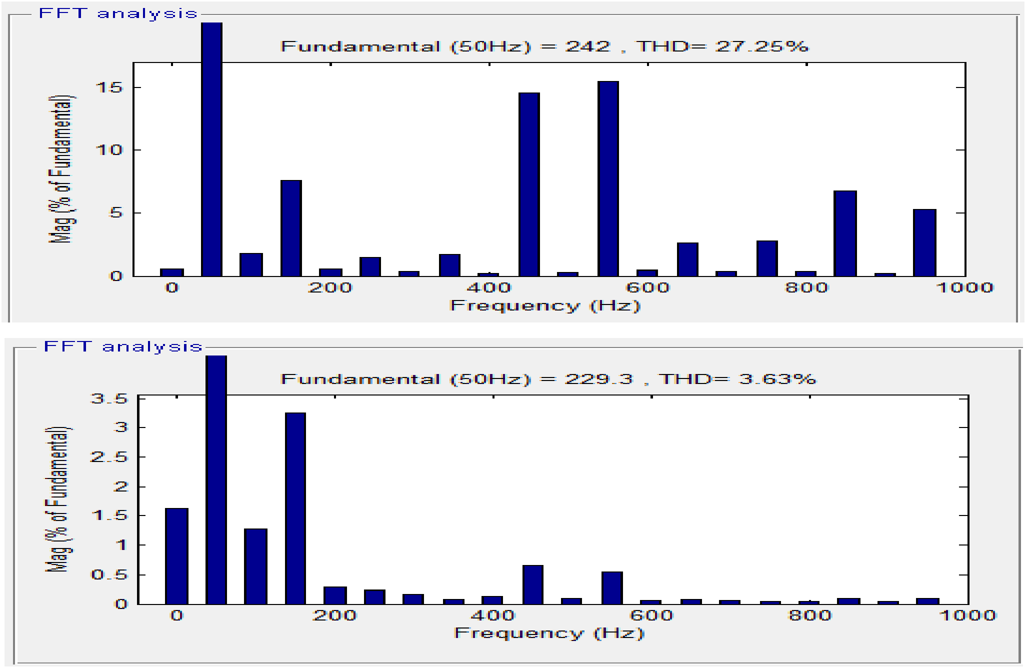

Fig. 11 Three phase five level output voltage and FFT analysis of the closed loop system with filter for RL load

Hence from fig. 11 it gives the clearance as analysis of closed loop system will get better performance and less harmonic distortion compared with open loop system for with filter (27.25%) and without filter (3.63%) . Hence with the filter the output voltage is 260 Volts DC and for the voltage control the PI controller is used in the feedback loop.

VI.CONCLUSION

In this paper the comparison of open loop and closed loop performance of the nine phase transformer through multi level inverter base stand alone system. Hence by using the nine phase transformer it is more convenient to connect the wind generation units into the system and by using the multi level inverter the THD performance is improves. And also discussed the pulse generation techniques, in those phase opposition disposition pulse width modulation is better because of low THD (27.25%) and it is a better DC utilization than sinusoidal pulse width modulation. All the simulation results presented for both open and closed loop systems are simulated by using the MATLAB/SIMULINK.

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BIOGRAPHY

	**D.Anusha** received her B.Tech Degree in Electrical & Electronics Engineering from Raghu engineering college, Visakhapatnam, under JNTU Kakinada in 2013. Currently she is pursuing her M.TECH Degree in Power Electronics & Drives from GMR institute of technology, Rajam, AP, India. Her research interest includes power electronics and renewable energy sources. She has published one paper in National Conference and one paper in international journal.
	**L.Venkatasuresh Kumar** received B.Tech (EEE) degree, from St.theressa institute engineering and technology under JNTU Hyderabad in 2008 and M.TECH (power and energy system) from college of National Institute of Technology Karnataka Surathkal in 2010. Presently working as Assistant professor in GMR institute of technology, Rajam, AP, India. He is currently working toward the part time Ph.D. degree in the Future Renewable Electric Energy Systems, Department of Electrical and electronics Engineering, GITAM University, Visakhapatnam, Andhra Pradesh, India His research interest on is conversation, control, optimization and integration with renewable energy recourses.